Appendix A
Hydrologic Analysis Methods and Results

1.1 Introduction

This appendix details the methodology used to obtain the hydrologic inputs to the Grande Ronde River HEC-RAS model. The Grande Ronde River drains the Wallowa and Blue Mountains of northeast Oregon and southeast Washington and has a basin area of 4,104 square miles (USGS 2019a). The modeled portion of the basin incudes the tributaries and the last approximately 40 miles of the mainstem in Washington before entering the Snake River. A map of the model extent is shown in Figure A-1.

1.2 Peak Flow Hydrology

Peak flow profiles were developed for the 2-, 5-, 10-, 25-, 50-, and 100-year events for both the mainstem Grande Ronde River above the U.S. Geological Survey (USGS) gage at Troy, Oregon, and the tributaries of the mainstem and Joseph Creek. The additional flow of each tributary was added in at the nearest cross section downstream of the creek mouth in the HEC-RAS model.

1.2.1 Mainstem Upstream of Troy Gage

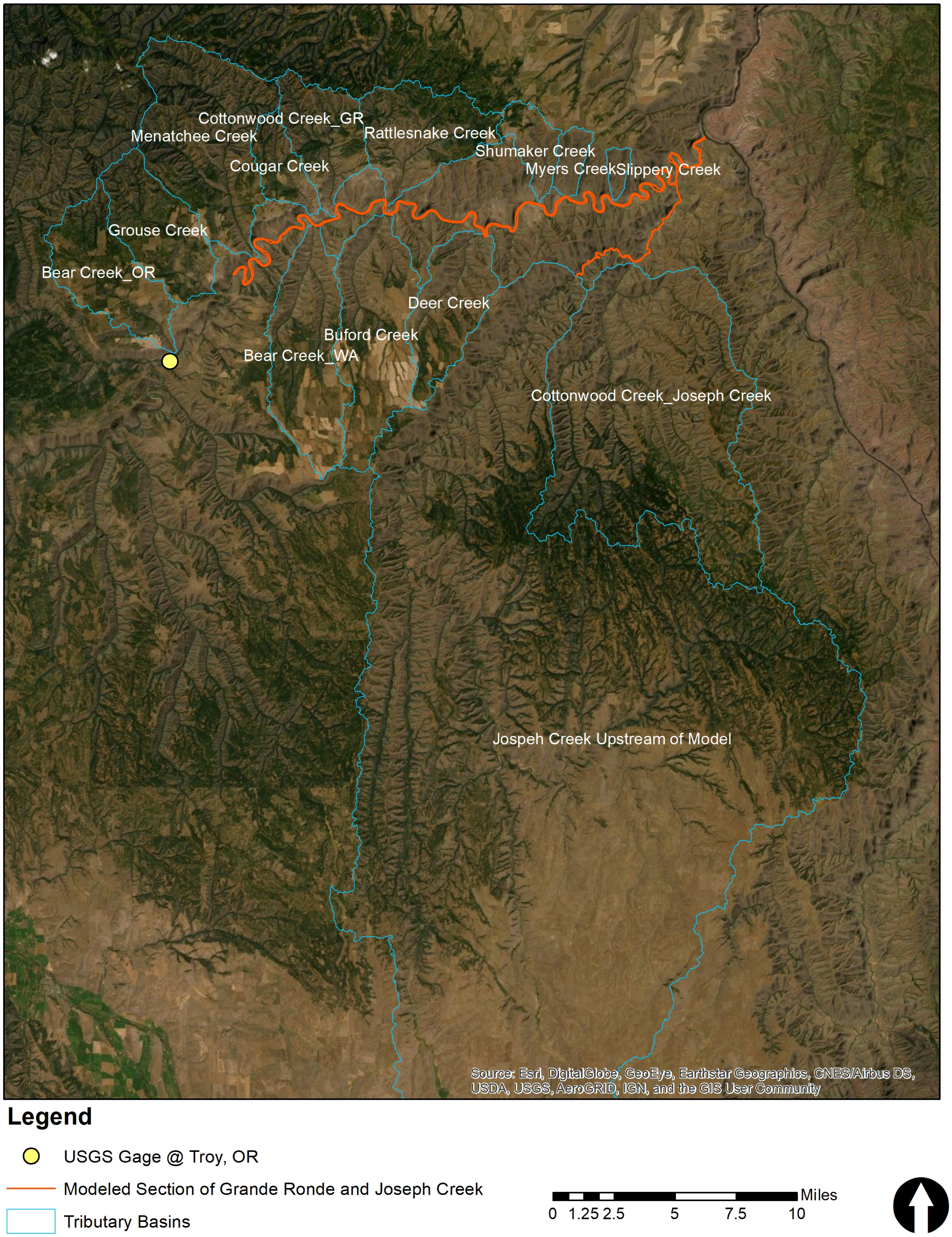
The USGS gage 13333000 at Troy, Oregon, has daily data and annual peak flow data from water year 1945 to present (USGS 2019b). The annual peak flow data taken from the USGS website were analyzed using a Log-Pearson Type III distribution to determine the recurrence intervals for the 2- to 100-year floods. The results for the mainstem upstream of Troy are shown in Table A-1.

Table A-1
Peak Flow Profiles for the Mainstem Above Troy, Oregon

Return Interval	Discharge (cfs)
2-year	14,895
5-year	22,001
10-year	27,152
25-year	34,148
50-year	39,707
100-year	45,560

cfs: cubic foot per second

Figure A-1
Grande Ronde Hydrologic Model Overview



1.2.2 Tributaries

There were no gages on any of the tributaries of the Grande Ronde River or Joseph Creek, so regressions from the USGS StreamStats database were used to determine peak flow profiles for these tributaries (USGS 2019a). In the StreamStats database, the peak flow profiles from the tributaries with outlets in Washington were calculated directly from the website using a regression equation that accounted for basin area, mean annual precipitation, and basin percent forest cover (Mastin et al. 2016). The flow profiles from the tributaries Bear Creek and Grouse Creek in Oregon were manually calculated using the same regression equation from Mastin et al. 2016 as shown in Equation A-1. The constants from Region 1 encompassing southeast Washington and Northeast Oregon were used, and the basin area, annual precipitation, and percent forest cover were obtained using the data in the StreamStats database (USGS 2019a).

Equation A-1 (Mastin et al. 2016)

$$Q = \frac{aA^{b}\,10^{cP}}{10^{dCAN}}$$

where:

a,b,c,d = given constants for the particular regression region and recurrence interval

A = basin area (mi^2)

P = mean basin annual precipitation (in)

CAN = basin % forested

Regression region	Number of stations used in analysis	Form of the regression equation	Annual exceedance probability	Constant	Coefficents			S_p (percent)	R^2_{pseudo}	SEM (percent)	Range of values		
				a	*b*	*c*	*d*				*A*	*P*	CAN
1	93	$Q = aA^{b}10^{cP}/10^{dCAN}$	0.5	3.846	0.745	0.032	0.0078	95.04	85.1	90.72	0.25–3,304	9.82–52.45	0.0–77.4
			0.2	12.106	0.713	0.028	0.0098	71.93	87.66	68.33			
			0.1	22.080	0.695	0.026	0.0107	70.67	86.72	66.91			
			0.04	42.170	0.674	0.024	0.0117	77.42	83.38	73.12			
			0.02	63.826	0.661	0.023	0.0124	84.76	80.32	79.92			
			0.01	92.470	0.649	0.022	0.0130	93.55	77.01	88.08			
			0.005	129.42	0.637	0.021	0.0136	103.98	73.32	97.75			
			0.002	193.20	0.624	0.020	0.0143	118.69	68.66	111.33			

1.3 Low Flow Hydrology

A summer low flow, winter low flow, and 1-year profile were also developed for all the tributaries and the mainstem. For the summer low-flow profiles, the 50% flow duration discharges from the three lowest flow months of August, September, and October were averaged. For the winter low-flow profiles, the 50% flow duration discharges from the months of December, January, and February were averaged. For the tributaries, 1-year profiles were calculated by interpolating the 2- to 100-year flood data from the StreamStats database and extrapolating a 1-year flow. For the mainstem, the 1-year profile was calculated using the Log-Pearson Type III distribution.

1.3.1 Mainstem Upstream of Troy Gage

The summer and winter low flows for the mainstem upstream of the gage were taken from the online gage data by averaging the monthly average discharges for August to October and December to February, respectively (USGS 2019b). The 1-year flow for the mainstem upstream of the USGS gage was estimated using the same Log-Pearson Type III distribution on the annual peak data going back to water year 1945 (USGS 2019b).

1.3.2 Tributaries

1.3.2.1 Summer and Winter Low Flows

The USGS StreamStats database only offered low-flow calculations for basins in Oregon, so the regression equations from Region 6 for Northeast Oregon were used to calculate the August to October and December to February 50% flow durations for all the tributaries in Washington (Risley et al. 2008). The results were then verified by comparing the hand calculated results for Bear Creek and Grouse Creek in Oregon to the automatic outputs from the USGS StreamStats database. The regressions from Risley et al. 2008 for monthly 50% flow duration differ by month and were dependent on a variety of parameters including basin drainage area, basin mean precipitation, basin drainage density, and basin maximum, minimum, and mean elevation (Risley et al. 2008). The equations for each month are shown in Equation A-2. Drainage density was obtained by delineating stream networks in GIS, dividing stream length by basin area, and normalizing the drainage density values for each tributary to the results obtained from the StreamStats database for Grouse and Bear creeks in Oregon (USGS 2019a). Basin max, min, and mean elevations were determined in GIS for the basins in Washington. The remainder of the parameters were obtained from the StreamStats database (USGS 2019a).

Equation A-2 (Risley et al. 2008)

Monthly 50% Flow Duration

August:

$$P50 = 1.27 * 10^{-17.3} * DA^{.843} * P^{3.53} * XE^{2.95}$$

September:

$$P50 = 1.40 * 10^{-17.9} * DA^{.912} * P^{4.06} * XE^{2.85}$$

October:

$$P50 = 1.24 * 10^{-15.8} * DA^{.933} * P^{3.59} * XE^{2.49}$$

December:

$$P50 = 1.07 * 10^{-2.89} * DA^{.974} * P^{2.15} * DD^{-.968} * NE^{-.277}$$

January:

$$P50 = 1.07 * 10^{-1.56} * DA^{.906} * P^{2.05} * NE^{-.533}$$

February:

$$P50 = 1.05 * 10^{1.59} * DA^{1.02} * P^{1.87} * E^{-1.33} * DD^{-.802}$$

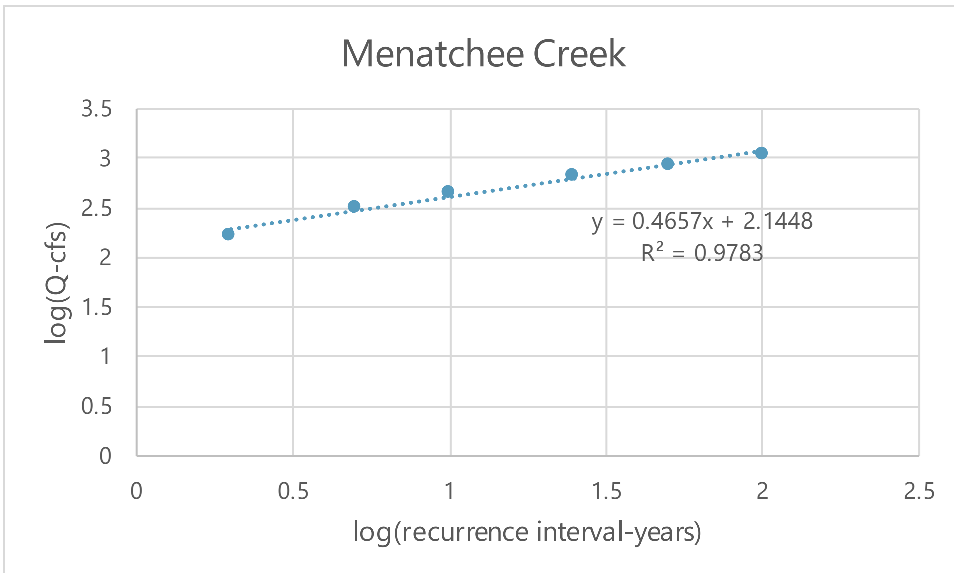
where:

P	=	mean annual basin precipitation (in)
DA	=	basin drainage area (mi^2)
XE	=	basin max elevation (ft)
NE	=	basin min elevation (ft)
DD	=	drainage density (km/km^2)
E	=	basin mean elevation (ft)

1.3.2.2 1-Year Flows

The 1-year flows for all the tributaries were estimated by graphical interpolation using the discharges for the 2- to 100-year peak floods previously obtained from the StreamStats database. The 2- to 100-year floods for each creek were plotted on a log-log plot, and the linear trendline was calculated and used to determine the 1-year flood. The same graphical method was used to estimate the 1-year flood for the mainstem gage data at Troy for which we had an accurate 1-year flood determined from the Log-Pearson Type III method. The difference between the graphical method and the Log-Pearson Type III method for the mainstem data was then used as a multiplicative correction factor to correct all the tributary values to obtain a more accurate set of 1-year discharges. An example of the graphical interpolation process is shown in Figure A-2.

Figure A-2
Graphical Interpolation to Determine 1-Year Discharge for Tributaries



1.4 Final Model Hydrology

The final inputs to the HEC-RAS model including the peak flow and low-flow profiles are shown in Table A-2. The discharge for the mainstem Grande Ronde River upstream of the gage at Troy was added to the discharges from Bear and Grouse creeks in Oregon to comprise the flow "Grande Ronde Upstream of Model." Each tributary flow is added to the total, and the two flow change locations on Joseph Creek are added to the Grande Ronde below Slippery Creek to get the largest discharge value "Junction of Joseph Creek and Grande Ronde."

Table A-2
Model Hydrology

Tributary/ Location Name	Flow (cfs) per Return Period							Summer Low Flow (cfs)	Winter Low Flow (cfs)
	1-year	2-year	5-year	10-year	25-year	50-year	100-year		
Grande Ronde Upstream of Model	5,596	15,084	22,348	27,636	34,844	40,595	46,658	794	2,367
Menatchee Creek	5,678	15,251	22,667	28,090	35,509	41,454	47,738	795	2,376
Cougar Creek	5,695	15,288	22,748	28,215	35,708	41,724	48,093	796	2,377
Bear Creek_WA	5,758	15,419	23,041	28,663	36,418	42,689	49,353	796	2,382
Cottonwood Creek_Grande Ronde	5,790	15,487	23,190	28,888	36,772	43,166	49,973	796	2,384
Rattlesnake Creek	5,826	15,561	23,345	29,119	37,127	43,638	50,580	796	2,387
Buford Creek	5,906	15,729	23,722	29,698	38,046	44,888	52,220	796	2,393
Deer Creek	5,953	15,828	23,947	30,047	38,605	45,653	53,230	796	2,396
Shumaker Creek	5,972	15,868	24,046	30,208	38,875	46,033	53,744	796	2,397
Myers Creek	5,984	15,893	24,113	30,319	39,067	46,309	54,125	796	2,398
Slippery Creek	5,992	15,910	24,158	30,396	39,202	46,505	54,398	796	2,398
Junction of Joseph Creek and Grande Ronde	6,660	17,255	26,769	34,103	44,602	53,465	63,078	803	2,492
Joseph Creek Upstream of Model	528	1,060	2,040	2,880	4,170	5,350	6,650	5	77

1.5 References

Mastin, M.C., C.P. Konrad, A.G. Veilleux, and A.E. Tecca, 2016. *Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014*. Version 1.1, October 2016. U.S. Geological Survey Scientific Investigations Report No. 2016–5118, 70 pp. Available at: https://pubs.er.usgs.gov/publication/sir20165118.

Risley, J., A. Stonewall, and T. Haluska, 2008. *Estimating flow-duration and low-flow frequency statistics for unregulated streams in Oregon*. U.S. Geological Survey Scientific Investigations Report 2008-5126, 22 pp. Available at: https://pubs.usgs.gov/sir/2008/5126/.

USGS (U.S. Geological Survey), 2019a. StreamStats in Washington and Oregon. Available at: https://streamstats.usgs.gov/ss/.

USGS, 2019b. Monitoring Location 13333000, Grande Ronde River at Troy, Oregon. Accessed July 2019. Available at: https://waterdata.usgs.gov/or/nwis/inventory/?site_no=13333000&agency_cd=USGS.